

We claim:

1. An apparatus for softening water, the apparatus comprising:

at least one nanofiltration filter element configured to reject at least 80 percent of calcium ions, and configured to:

5 a) receive an input flow of hard water,

b) discharge an output flow of permeate water comprising at least 80 percent of the input flow, and

c) discharge an output flow of non-permeate water comprising less than 20 percent of the input flow;

10 wherein the output flow of permeate water has a lower hardness than the output flow of non-permeate water.

2. The apparatus for softening water of claim 1, wherein the nanofiltration element is configured to receive an input flow of hard water at a pressure below 250 psi.

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3. The apparatus for softening water of claim 1, wherein the nanofiltration element has a molecular weight cut-off of 20 to 500.

4. The apparatus for softening water of claim 1, wherein the water flux through the
20 nanofiltration element is at least 75 liters per square meter per hour.

5. The apparatus for softening water of claim 1, wherein the nanofiltration element has a calcium ion rejection rate greater than 85 percent.

6. The apparatus for softening water of claim 1, wherein the nanofiltration element has a calcium ion rejection rate greater than 90 percent.

5 7. The apparatus for softening water of claim 1, wherein the nanofiltration element is configured to discharge an output flow of permeate water comprising at least 90 percent of the input flow.

8. The apparatus for softening water of claim 1, wherein the peak output flow rate
10 of permeate water is less than 10 gallons per minute.

9. The apparatus for softening water of claim 1, wherein the nanofiltration filter element has an average pore size that permits the passage of water and monovalent ions but substantially prevents the passage of divalent ions.

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10. The apparatus for softening water in accordance with claim 1, wherein the apparatus does not substantially increase the total salt levels relative to the input flow of water.

20 11. The apparatus for softening water in accordance with claim 1, wherein the nanofiltration filter element comprises a positively charged membrane.

12. The apparatus for softening water in accordance with claim 1, wherein the input flow comprises potable water.

13. The apparatus for softening water in accordance with claim 1, wherein the output
5 flow of permeate water has a hardness below 3.5 grains per gallon.

14. The apparatus for softening water in accordance with claim 1, wherein the apparatus is configured and arranged to have an output flow of permeate water of 200 gallons or more per 24-hour period.

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15. Water softened using the apparatus of claim 1.

16. An apparatus for softening water, the apparatus comprising:
at least one nanofiltration filter element configured to reject at least 85 percent of
15 divalent hardness ions, and configured to:

a) receive an input flow of hard water,

b) discharge an output flow of permeate water comprising at least 90 percent of the input flow, and

c) discharge an output flow of non-permeate water comprising less than 10
20 percent of the input flow;

wherein the output flow of permeate water has a lower hardness than the output flow of non-permeate water.

17. The apparatus for softening water of claim 16, comprising one nanofiltration element.

18. The apparatus for softening water of claim 16, comprising two or more
5 nanofiltration elements.

19. The apparatus for softening water of claim 16, wherein the nanofiltration element has a rejection rate of greater than 90 percent.

10 20. The apparatus for softening water of claim 16, wherein the apparatus has a water recovery rate of at least 90 percent.

21. The apparatus for softening water of claim 16, wherein the peak flow rate is from 5 to 10 gallons per minute.

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22. The apparatus for softening water of claim 16, wherein the nanofiltration element has a molecular weight cut-off of 20 to 500.

23. The apparatus for softening water of claim 16, wherein the nanofiltration filter
20 element has an average pore size that permits the passage of water and monovalent ions but substantially prevents the passage of divalent ions.

24. The apparatus for softening water in accordance with claim 16, wherein the apparatus does not substantially increase the total salt levels relative to the input flow of water.

5 25. The apparatus for softening water in accordance with claim 16, wherein the input flow is provided at a pressure of less than 200 pounds per square inch.

26. The apparatus for softening water in accordance with claim 16, wherein the nanofiltration filter element comprises a positively charged membrane.

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27. The apparatus for softening water in accordance with claim 16, wherein the input flow comprises potable water.

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28. The apparatus for softening water in accordance with claim 16, wherein the output flow of permeate water has a hardness below 3.5 grains per gallon.

29. The apparatus for softening water in accordance with claim 16, wherein the apparatus is configured and arranged to have an output flow of permeate water of 200 gallons or more per 24-hour period.

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30. Water softened using the apparatus of claim 16.

31. A method for softening water, the method comprising:

providing at least one nanofiltration filter element configured reject at least 80 percent of calcium ions:

receiving an input flow of water having at least 2 grains of hardness per gallon;

discharging a first output flow of permeate water comprising at least 80 percent of
5 the input flow, and which has passed through the nanofiltration filter; and

discharging a second output flow of non-permeate water comprising less than 20 percent of the input flow, and which has not passed through the nanofiltration filter;

wherein the output flow of permeate water has a lower hardness than the output flow of non-permeate water.

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32. The method for softening water of claim 31, wherein the nanofiltration filter element has an average pore size that substantially permits the passage of water and monovalent ions but substantially prevents the passage of divalent ions.

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33. The method for softening water in accordance with claim 31, wherein the method does not substantially increase the total salt levels relative to the input flow of water.

34. The method for softening water in accordance with claim 31, wherein the input flow is provided at a pressure of less than 200 pounds per square inch.

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35. The method for softening water in accordance with claim 31, wherein the input flow is provided at a pressure of 140 to 200 pounds per square inch.

36. The method for softening water in accordance with claim 31, wherein the nanofiltration filter element comprises a positively charged membrane.

37. The method for softening water in accordance with claim 31, wherein the output
5 flow of permeate water contains greater than 90 percent of the input flow.

38. The method for softening water in accordance with claim 31, wherein the output flow of permeate water has a hardness below 3.5 grains per gallon.

10 39. The method for softening water in accordance with claim 31, wherein the method is configured and arranged to have an output stream of permeate water of 200 gallons or more per 24 hour period.

40. Water softened using the method of claim 31.

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